Renewable and Sustainable Energy Reviews 16 (2012) 4190–4195

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Biomass potential in Andalusia, from grapevines, olives, fruit trees and poplar, for providing heating in homes

J.M. Rosúa [a,*], M. Pasadas [b]

[a] Building Engineering Faculty, University of Granada, 18071 Granada, Spain
[b] Department of Applied Mathematics, E.T.S.I.C.C.P., Campus Fuentenueva s/n, University of Granada, 18071 Granada, Spain

ARTICLE INFO

Article history:
Received 11 February 2011
Accepted 18 February 2012
Available online 28 April 2012

Keywords:
Biomass
Crops
Grapevines
Olive
Fruit trees
Poplar
Home heating
Andalusia

ABSTRACT

Conventional energy resources, has been shown to be limited and they are producing environmental degradation. So the transition to an energy model based on the use of renewable energy is an urgent need. The energy and environmental policies are evidence of this and they are being implemented out a multitude of countries worldwide, furthermore one important element in this transition is the increased use of biomass for energy production.

Agricultural residues are produced in huge quantities in all countries; most of these could be used for energy generation. This property increases the value of waste materials and reduces the environmental impacts of waste disposal. This paper analyzes the situation of biomass energy resources in Andalusia, and quantifies the pruning obtained from different crop kinds: grapevines, olives, fruit trees and poplar plantations. All this biomass is destined for energetic use in domestic heating. In addition, it could be some additional revenue for fruit producers, whereas to achieve a more sustainable bioenergetic system.

We estimate the measures of the planting area of all mentioned crops in Andalusia. The main goal is to determine the amount of usable energy from the biomass. But we consider only pruning of trees.

The results show that most of the biomass is originated from olive pruning. Besides the entire biomass from crops with grapevines, olives, fruit trees and growing part of poplar plantations, we could supply a large percentage of the total energy consumed for annual home heating in Andalusia (2007).

Contents

* Corresponding author. Tel.: +34 958 243130; fax: +34 958 249513.
E-mail address: jmrosua@gmail.com (J.M. Rosúa).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2012.02.035

1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries [1]. Energy consumption in developed countries grows at a rate of approximately 1% per year, and that of developing countries, 5% per year [2].

The unsustainability of the present production-consumption energy model highlights the finite nature of conventional energy resources, as well as the environmental degradation inherits in such as model [3]. Present reserves of oil and natural gas can only cover consumption at this rate for the next 40 years in the case of oil, and for the next 60 in the case of natural gas [4]. The predictable shortage of fossil fuel in the near future has triggered an urgent search for alternative, sustainable energy sources [5].

Biomass, especially wood, has traditionally been an important source of energy particularly attractive nowadays because of its inherent nature of being environmentally friendly and renewable [6]. Biomass is one of the major energy sources today, contributing approximately 14% of the world's annual energy consumption in comparison to 12% from coal and 15% from gases [7]. As a renewable source of energy, biomass offers environmental benefits with easy availability of feedstocks including agricultural and forestry residues and wastes. There are growing interests of developing efficient biomass thermal conversion technologies worldwide to combat climate change and to provide solutions for the current energy crisis [8].

In the next section, we describe the biomass term, Section 2.1, and specifically what are the varieties of crops that we have considered in this study, Section 2.2. In Section 3, we locate geographically Andalusia, Section 3.1, we describe the consumption energy evolution, Section 3.2 and the renewable energy policy that it is take place in this community, Section 3.3, and in Sections 3.4 and 3.5, we determinate the energetic resources from biomass in Andalusia and Spain respectively. In Section 4, we quantify the energy consumption for heating houses, in order to establish, in Section 5, the study's conclusions relating to energy consumption that could be supplied by biomass quantified.

2. Biomass energy

2.1. Biomass

Biomass is the raw material used in the manufacture of biofuel [9], and the Spanish Association for Standardization and Certification (AENOR) uses the European Technical Specification CEN/TS 14588 definition, that it refers Biomass as "any material of biological origin excluding those who have been enshrined in geological formations undergoing a mineralization process".

It is considered that the biomass is a renewable energy source because its value comes from the sun. Through the process of photosynthesis, due to chlorophyll, plants capture solar energy and convert carbon dioxide from the air (CO_2) and ground water in carbohydrates to form organic matter. When these carbohydrates are burned, return to form carbon dioxide and water, releasing it that they contain.

Biomass resources, include any organic matter source, as agricultural and forestry wastes, aquatic plants, animal waste and garbage. Their availability varies depending on the region, according to climate, ground type, geography, population density, productive activities, etc. According to the above, Jiménez Gómez (1991) says biomass term includes hydrocarbon materials, non-fossil, which means the photosynthesis process, there was reduction and fixation of CO_2.

It calls solid biofuels, to the solid biomass that can draw power directly through thermochemical processes such as combustion. Sources of solid biofuels are often classified into [10]:

- Primary sources of solid biofuels:
  - Energy crops.
  - Harvested forest biomass for energy purposes. Forest biomass holds a significant position for energy production in developing countries. Its importance is elucidated through various activities performed by the rural industries [11].
- Secondary sources of solid biofuels, also known as dry waste biomass:
  - Agricultural products (plant debris produced during the treatments applied to the crop: straw, sugar cane and fruit pruning), forestry (remains of silvicultural interventions, such as branches and trees without commercial value) and industry (sawdust, almond shells, olive pits, etc.).

2.2. Crops included in the study

To carry out the assessment of the biomass potential from pruning and harvesting of the following categories of trees, we need to know the characteristics of these types of crops, planting areas, as well as planting density and the amount usabled in the process of each type of trees.

The olive tree (*Olea europaea* var. *European*) is an evergreen tree of the Oleaceae family, present in countries with Mediterranean climates and the main species used in this region.

Once in a while it is necessary a performer pruning of the tree and all varieties need more light pruning to be done annually.

The heating value is meaning as the heat emitted per kilogram of fuel complete combustion at constant pressure of 1 kg/cm^2 [12]. This is tempered by higher heating value concept (HHV) and lower heating value concept (LHV) [9]; its variation depends on the moisture content of the sample. The heating value established for the olive tree pruning remains is 17.991 MJ/kg (L_0HV) and 19.246 MJ/kg (H_0HV) [13].

The grapevine (*Vitis vinifera* L.). The *Vitis* genus comprises about 65 species of deciduous shrubs or vines, creeping or climbing, to *Vitaceae* family.

The common grapevine is a woody shrub stems short and thick (stump), very twisted and with many knots. Of them branches are born, long and gnarled, with woody consistencies. This species is cultivated in most of southern and central Europe, northern Africa and western Asia.

The vine shoot, that is the crop remains, has a LHV of 16.736 MJ/kg with the 10% of humidity [10].

Fruit trees are hardwoods high heating value, we consider a LHV through 17 MJ/kg.

The poplar (*Populus* spp.) belongs to the *Salicaceae* family. This deciduous plant is very naturally present along the northern hemisphere.

Its multiplication is performed, usually through coppice, and implementation can be done in early autumn or late winter-early spring, depending on the weather conditions in the area. To this end, we highly variable planting patterns, generally small and may reach sub-meter spacings, which would achieve higher densities than 10,000 plants/ha (in contrast to what happens in forest plantations: 300 or 400 plants/ha). We have considered 2.5 m $\times$ 3 m planting patterns.

Harvesting is realized in pruning shifts not exceeding 5 years (short shifts of 2 years in the case of certain plantations for exclusive energy use), and the number of years between two consecutive harvests varies between 2 and 5 years. Since after each pruning the grapevines sprout again, it is estimated that plantation life can exceed 15 years.

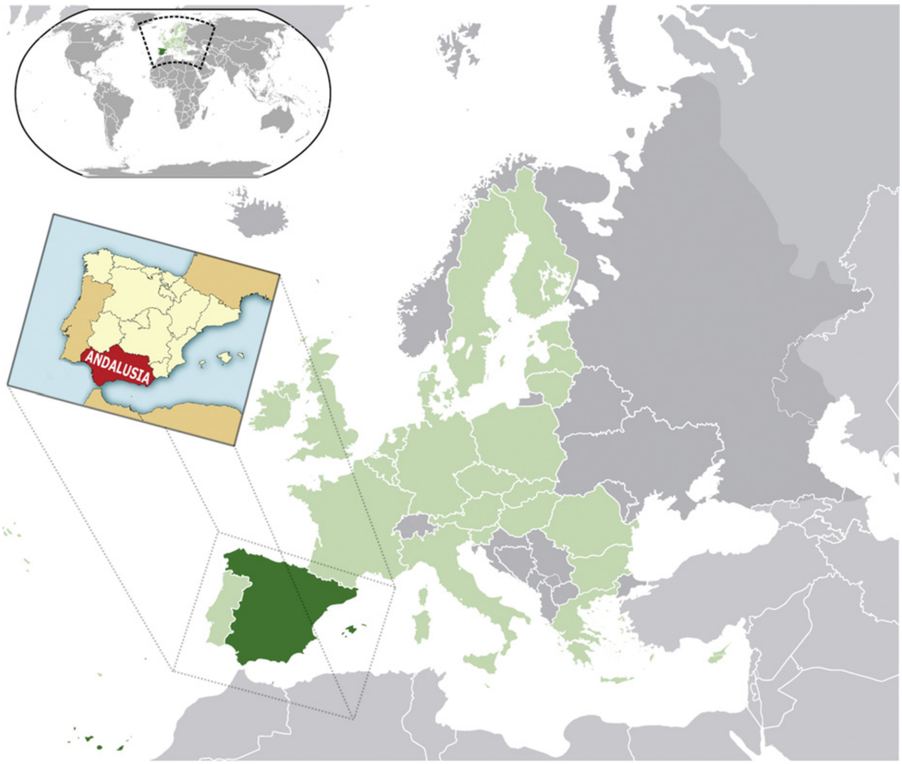


Fig. 1. Andalusia geographic location.

Table 1
Planting densities of specific crops in this study [17,18].

Crops	Planting density
Olive tree	70 trees/ha
Grapevine	1868 vines/ha
Fruit tree	About 400 trees/ha
Poplar	1320 trees/ha

This kind of trees, are adapted to diverse climatic which have water. The optimum growth temperature is 15 °C and 25 °C, with minimum temperatures of 5–10 °C and its maximum is 30–40 °C [14].

With respect to annual production of dry matter per year, there are references about they can exceed 20 t dm/ha year [15], although Bacher [14] provides the average biomass production between 12 and 15 t dm/ha year. From Spain production with different edaphic conditions and different clones as well as different densities and pruning shifts [16] we can observe the wide variability that occurs as a consequence of the use of different culture conditions (8–17 t dm/ha year). We take an average annual production 13 t dm/ha year.

The estimated heating value for poplar wood is 17.154 MJ/kg (LHV) (Curcho Zaragoza, 2007).

About planting densities of each crops specified in the study, they are listed in Table 1.

To calculate the kg of crops waste per year, we consider the following values (Table 2).

Table 2
Amount of waste in dry matter per year and species [10].

Crops	Waste (dry matter)/year
Olive tree	8 kg/tree
Grapevine	0.5 kg/vine
Fruit tree	2.5 kg/tree
Poplar	13 t/ha cultivated

3. Energy situation in Andalusia

3.1. Geographic location

Andalusia autonomous community is located in southern Spain (Fig. 1), between latitudes 37° and 42° N, with an area of 87,268 km^2. It is the most populated of Spain and second most extensive, occupies approximately 17.29% of total Spanish territory. It is made up for eight provinces: Almeria, Cadiz, Cordoba, Granada, Huelva, Jaen, Malaga and Seville.

3.2. Energy consumption in Andalusia

The primary energy consumption in the European Union stands at 1806.4 Mtoe, of which about 1.1% corresponds to Andalusia (Fig. 2).

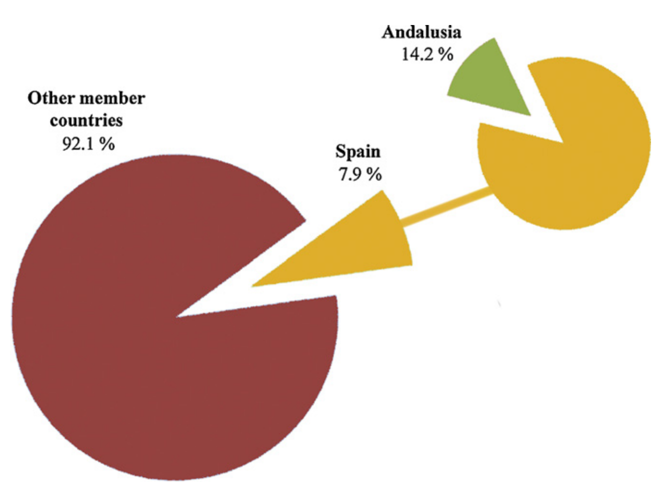


Fig. 2. Primary energy consumption 2008 [19].

Table 3
Primary energy evolution from biomass sources [21].

Period	2000	2001	2002	2003	2004	2005	2006	2007	2008
Biomass (ktoe)	789.4	794.0	900.3	846.4	849.0	867.2	670.9	901.6	1266.7

Table 4
Energy production evolution from biomass for internal consumption [21].

Period	2000	2001	2002	2003	2004	2005	2006	2007	2008
Biomass (ktoe)	789.4	794.0	900.3	825.4	828.0	849.7	627.2	851.1	1200.0

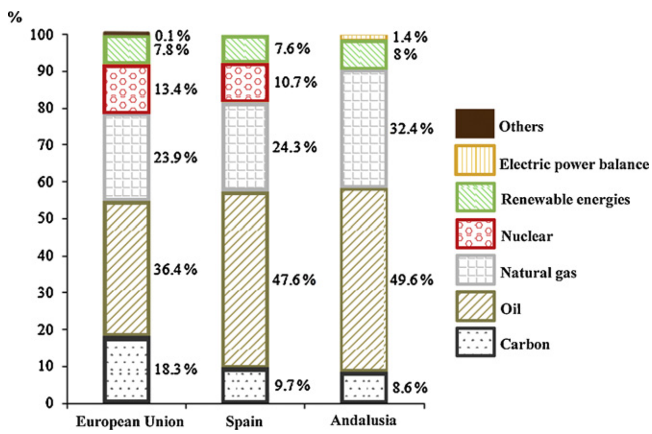


Fig. 3. Structure of primary energy sources [20].

In Spain, the primary energy consumption in 2008, was 142,070 ktoe (3.1% down on 2007), of which 7.6% came from renewable energy sources (Fig. 3).

In Andalusia, for the same period, the primary energy consumption was 20,143.8 ktoe (14.2% of total national consumption), of which 1610 ktoe came from renewable energy sources (78.7% from biomass).

About self-sufficiency degree, domestic energy production in the same year was 30,725 ktoe, so the self-sufficiency in primary energy in Spain is established at 21.6%, while in Andalusia is less than 10% (9.1%), both quantities well below the average of the other territories of the European Union (46.9%).

The following table (Table 3 and Fig. 4) shows the primary energy evolution from biomass in Andalusia during the period 2000–2008.

Energy production evolution from biomass for internal consumption during this period has been as we can see in Table 4 and Fig. 5.

The participation of renewables in final energy consumption in Andalusia is 4.0%, close to the 5.5% present in the European Union level.

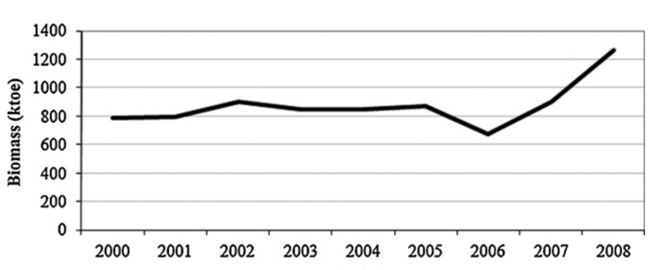


Fig. 4. Biomass consumption evolution in Andalusia.

The aim of this study is to see what percentage of energy consumed annually in domestic heating may be supplied by biomass energy sources, whose origin has been specified in this work.

3.3. Renewable energy policy in Andalusia

In the mid 90s, energy policy was aimed at boosting renewable energy, through a bonus system, being the largest wind energy development (in 2009 was 13.8% of the total electricity demand in Spain).

The objectives of the Renewable Energies Promotion Plan 2005–2010, as a revised Renewable Energies Development Plan 2000–2010 are, coverage in 2010:

a) 12% primary energy demand through renewable sources (7.6% in 2008) [19].
b) 29.4% electricity demand through this same sources of energy (26% in 2008) [19].
c) 5.75% of fuels used in transport will be biofuels (1.1% recorded in 2007) [22].

Currently, and for continue this Plan, is developing the Renewable Energy Spanish Plan 2011–2020 with new goals for the future energy map in 2020.

In terms of energy efficiency, is being carried out by the Action Plan 2008–2012 of the Spanish Energy Efficiency Strategy, which defines the potential savings and to develop measures in order to reduce energy intensity and thus closer to international commitments regarding the environment acquired.

3.4. Biomass energy in Andalusia

Andalusia has a cultivated area of 8,759,531.18 ha, of which 1,937,107.76 ha are crops for this study. The most widespread in this community is the olive tree, a species which accounts for 80% of the total area occupied by the 4 types of crops in Andalusia mentioned above: poplar, fruit trees, grapevines and olive trees (Table 5).

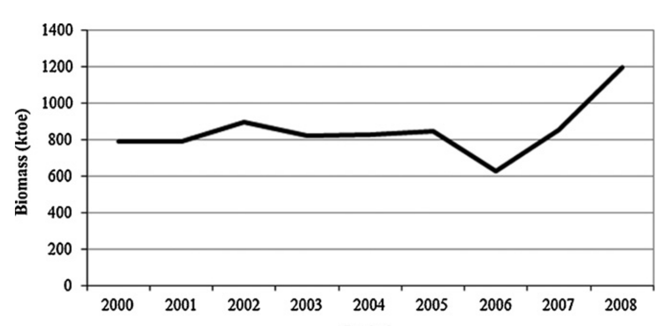


Fig. 5. Energy production evolution from biomass for internal consumption.

Table 5
Crop areas in Andalusia [10,23].

Crops	Area (ha)	Numbers of trees	Annual biomass (kg)
Poplar	16,799.94	22,175,920.80	218,399,220.00
Fruit trees	332,845.03	133,138,012.00	332,845,030.00
Olive trees	1,544,458.53	108,112,097.10	86,489,6776.80
Grapevines	43,004.26	80,331,957.68	40,165,978.84
Total	1,937,107.76		1,456,307,005.64

Table 6
Reduction coefficients to calculate the usable biomass [24].

Average slope	Biomass exploited (% generated from biomass)
$p < 12.5\%$	80
$12.5\% < p < 35\%$	60
$p > 35\%$	20

We assume that these species are grown in soil whose average slope does not exceed 12.5%, so the collection usable biomass equal to 80% of the annual biomass generated (Table 6).

After applying the reduction factor 0.8, we have the annual usable biomass potential in Andalusia, from such crops is approximately:

$$1,456,307\,\text{t} \times 0.8 = 1165045.6\,\text{t} \quad \text{usable biomass per year}$$

In Fig. 6, we can see the percentage share of the mentioned crops in Andalusia.

Assuming that the caloric value of biofuels is equal to the caloric value of wood from which it comes, and that the amount of poplar allocated to energetic crop is 30% of the total grown poplar in Andalusia (25% + 5% energy crop debris timber industry), the annual amount of energy from this biomass in the Autonomous Community of Andalusia appears in Table 7. To calculate the usable energy in olive trees, fruit trees and vines we just had in mind the pruning.

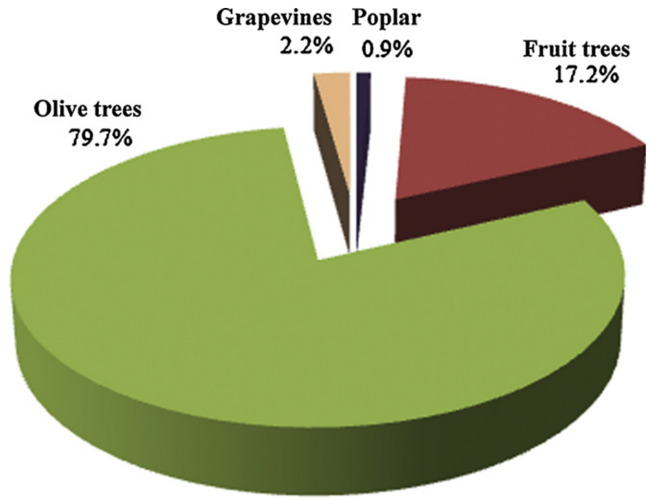


Fig. 6. Percentage of crops under study in Andalusia.

Table 7
Amount of usable energy in Andalusia.

Crops	Usable energy (MJ)	Usable energy (toe)
Poplar	969,692,536.80	
Fruit trees	4,526,692,408.00	
Olive trees	12,448,286,329.13	
Grapevines	537,774,257.49	
Total	18,482,445,531.42	441,741.05

3.5. Biomass energy in Spain

The result of the transactions for each of the autonomous communities in Spain is reflected in Table 8.

Notably, the high percentage of biomass potential representing Andalusia and Castile-La Mancha, which together produce nearly

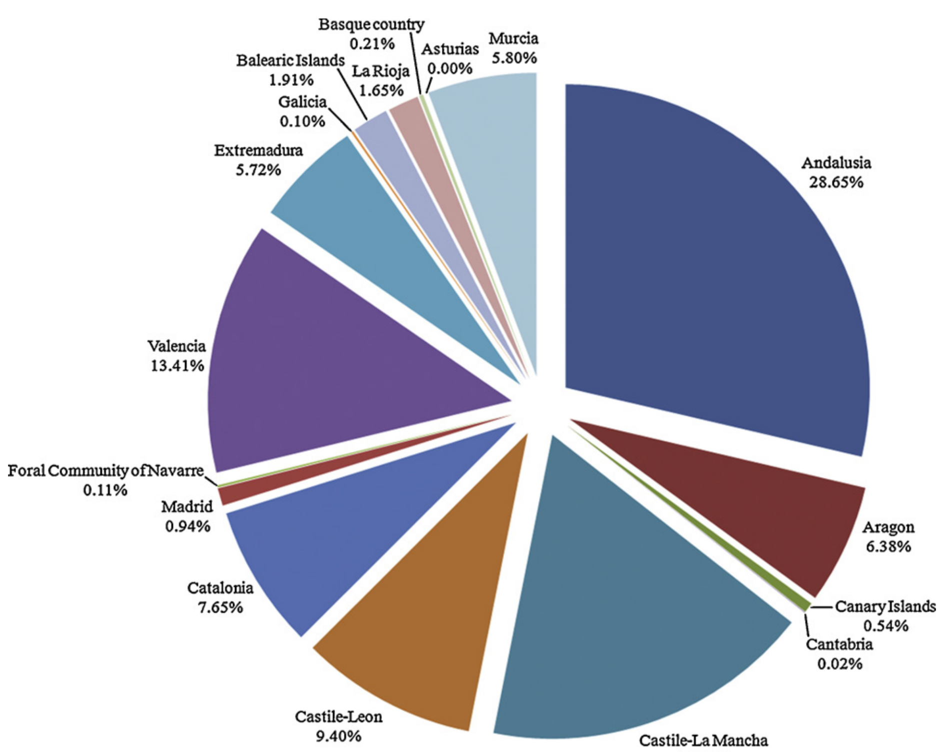


Fig. 7. Biomass production rates in Spain.

Table 8
Growing areas of autonomous communities in Spain.

Autonomous community	Total energy (toe)
Andalusia	441,741.05
Aragon	98,407.42
Canary Islands	8268.81
Cantabria	357.48
Castile-La Mancha	270,181.62
Castile-Leon	144,958.45
Catalonia	117,917.98
Madrid	14,448.75
Foral Community of Navarre	1677.39
Valencia	206,765.92
Extremadura	88,124.79
Galicia	1604.29
Balearic Islands	29,475.62
La Rioja	25,390.34
Basque Country	3264.02
Asturias	17.18
Murcia	89,375.70
TOTAL	1,541,976.81

50% of biomass residues originating with specified woody crops (Fig. 7).

Therefore, in Section 4, we study the energy needs for domestic heating that exist in the Autonomous Community of Andalusia, to try to determine the percentage that could be absorbed by this type of biofuel.

Represented by regions, the generation of this biomass is distributed as follows.

4. Energetic consumption for home heating

The energy consumed for heating homes in Spain during 2007 [19], was 7648.33 ktoe., representing 5.22% of total primary energy consumption in Spain in that year. Seen only in Andalusia, for the year 2007, energy consumption for heating of homes rose to 862,168 toe [25].

Thus, allocating the entire biomass established in the previous calculations, from the crops studied, could be generated annually 1,541,976.81 toe.

Knowing that the caloric value of pellets is about 18.83 MJ/kg, annual energy production of this biomass in Andalusia could reach 441,741.05 toe.

5. Conclusions

World energy consumption, oil crisis, greenhouse effect. . .everything that makes us reflect on the need for energy production systems, alternative to heavily exploited fossil fuels.

Biomass energy combines the concepts of non harming the environment and utilize the resources that nature gives us without destroyed, only transformed into another kind of energy, recovered somewhat to close the cycle of photosynthesis plants that produce more biomass.

In this study, we conclude that in Spain devoting 100% of biomass from pruning vines, olive and fruit trees and 30% of the total poplar crop for biofuel production, it covers 20.2% of energy needs for domestic heating homes in Spain (respect to consumption in 2007).

Knowing that the Autonomous Community of Andalusia is the most energy from this biomass produced in Spain, with 441,741.05 toe (28.65% of the national total), and assessing the need for heating energy only in this region, we find that devoting all energy produced in Andalusia, would cover 51.2% of the energy requirement for heating homes in this Community (also with respect to consumption in 2007), which demonstrates the validity of biomass as alternative energy source to fossil fuels heavily exploited and could be applied in many other regions with similar Andalusian crops.

References

[1] Acikgoz C. Renewable energy education in Turkey. Renew Energy 2011;36:608–11.
[2] Muneer T, Asif M, Munawwar S. Sustainable production of solar electricity with particular reference to the Indian economy. Renew Sustain Energy Rev 2005;9:444–73.
[3] Xiaowu W, Ben H. Energy analysis of domestic-scale solar water heaters. Renew Sustain Energy Rev 2005;9:638–45.
[4] Ridao ÁR, García EH, Escobar BM, Toro MZ. Solar energy in Andalusia (Spain): present state and prospect for the future. Renew Sustain Energy Rev 2007;11:148–61.
[5] Ong HC, Mahlia TM, Masjuki HH. A review on energy scenario and sustainable energy in Malaysia. Renew Sustain Energy Rev 2011;15:639–47.
[6] Grioui N, Halouani K, Zoulalian A, Halouani F. Thermogravimetric analysis and kinetics modelling of isothermal carbonization of olive wood in inert atmosphere. Thermochim Acta 2006;440:23–30.
[7] Seneca O. Kinetics of pyrolysis, combustion and gasification of three biomass fuels. Fuel Process Technol 2007;88:87–97.
[8] Shen DK, Gu S, Luo KH, Bridgwater AV, Fang MX. Kinetic study on thermal decomposition of woods in oxidative environment. Fuel 2009;88: 1024–30.
[9] Marcos Martín F. Biocombustibles sólidos de origen forestal. AENOR; 2001.
[10] Sebastián Nogués F, García-Galindo D, Rezeau A. Energías Renovables. Energía de la biomasa, vol. I. Prensas Universitarias de Zaragoza; 2010.
[11] Sattar MA. Role of forest biomass energy in developing countries. Renew Energy 1996;9:966–70.
[12] Kollman F. Tecnología de la Madera y sus aplicaciones. Ministerio de agricultura; 1959.
[13] European Comisssion (EC). Potencial y aprovechamiento energético de la biomasa del olivar en Andalucía. Junta de Andalucía. SODEAN; 2002.
[14] Bacher W. In: El Bassam N, James & James, editors. Energy plant species. Their use and impact on environment and development. London: Sciences Publishers Ltd; 1998. p. 203–6.
[15] Christersson L. Biomass production of intensively grown poplars in the southernmost part of Sweden: observations of characters, traits and growth potential. Biomass Bioenergy 2006;30:497–508.
[16] Ciria MP.El ciclo de vida de la producción de biomasa (energía y emisiones), III Congreso internacional de bioenergía: La bioenergía y el desarrollo rural. 2008.
[17] IDAE. Biomasa Cultivos energéticos. Ministerio de Industria, Turismo y Comercio; 2007. Avaibable at: <http://www.idae.es> [August 2010].
[18] El cultivo del olivo; El cultivo de las Naranjas; El cultivo de los Limones; El cultivo del Melocotón; El cultivo de las Mandarinas. Available at: <http://www.infoagro.com> [August 2010].
[19] MITYC. La energía en España. Ministerio de Industria, Turismo y Comercio; 2008. Available at: <http://www.mityc.es> [August 2010].
[20] Agencia Andaluza de la Energía. Andalucía en el contexto energético Europeo. Consejería de Innovación, Ciencia y Empresa – Junta de Andalucía; 2008.
[21] Agencia Andaluza de la Energía. Datos energéticos de Andalucía 2008. Consejería de Innovación, Ciencia y Empresa – Junta de Andalucía; 2007. Available at: <http://www.agenciaandaluzadelaenergia.es> [August 2010].
[22] APPA. Un informe de la Comisión Europea confirma con datos los beneficios socioeconómicos y ambientales logrados por los biocarburantes. Asociación de Productores de Energías Renovables; 2009. Available at: <http://www.appa.es> [August 2010].
[23] Ministerio de Medio Ambiente y Medio Rural y Marino. Informes de mapas de cultivos. Sistema de Información Geográfica de datos Agrarios (SIGA). Available at <http://.sig.marm.es/siga/> [August 2010].
[24] Freire E, Cabrera M, Blanco J. Evaluación de la biomasa energéticamente aprovechable en Galicia, procedente de los residuos forestales. Metoología para la cuantificación de estos recursos. Instituto Energético de Galicia; 1999. Available at: <http://www.orgaccmm.org> [August 2010].
[25] Agencia Andaluza de la Energía. Estadística Energética en Andalucía. Consejería de Innovación, Ciencia y Empresa – Junta de Andalucía; 2007.